Shifting baselines: the interdependency of local and national policies to reduce GHG emissions

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Abstract

Climate change and thus low-carbon transitions are global challenges, which require commitment and effort on all political levels. As international climate politics has approached its limits over the last two decades, the role of cities has simultaneously gained in importance. Many cities[1] worldwide have committed to ambitious climate protection targets, which often exceed national targets. However, cities cannot act in isolation. Their opportunities for action are embedded in an (inter)national policy framework, which may either support or hinder local actions. This gives rise to the question: which opportunities for climate protection do cities really have in a political system of multi-level governance?

This question can be illustrated using the city of Hamburg as an example for the German climate policy regime. The city aims to reduce its annual CO_2 emissions by 2 million metric tons and attempts to quantify the impact of local and national policies and actions using a bottom-up monitoring approach. We therefore analyse more than 400 local actions with respect to the induced CO_2 emission reductions. We also take a closer look at national and European policies and their impacts on local energy use and emissions. In total, 15 policies and instruments – broadly ranging from instruments to foster energy efficiency in residential and non-residential buildings, in appliances and in the transport sector, to support renewable energy sources (including biofuels) and to uptake CHP – are considered.

Our approach consists in measuring separately the impact of local and national policies and actions on urban CO_2 emissions. While the city of Hamburg has implemented many policies and actions, our results show that, a significant proportion of its CO_2 reduction is due to national policies, in the context of the German "Energiewende", which cannot or can only indirectly be influenced by the city. The results imply that local commitment and effort is essential in addressing the global challenge, yet ambitious targets can only be met in the presence of a supportive national policy framework. The analysis shows that many policies and measures implemented at national level require supportive structures and activities at local level in order to bridge information and implementation gaps of these measures.

Introduction

Cities are important actors in implementing ambitious national climate protection and energy targets for several reasons: first, a large share of greenhouse gas emissions is emitted in urban agglomerations. Second, cities are at the same time vulnerable to the impacts of regional climate change (OECD, 2010; UN-Habitat, 2011). Third, they are also experimental spaces for innovative processes, institutions and technologies and are therefore important drivers for sustainability innovations (Schneidewind and Scheck, 2012). Against this background, many European cities and regions have committed to very ambitious emission reduction targets until 2050 (80–95 %), have developed comprehensive sustainable energy or climate action plans and have implemented coherent policies and measures in relevant sectors. International and European urban networks such as the C40 net-

1. By using the term "city" we usually refer to the municipal government as a decision-making authority.

work and the Covenant of Mayors testify to a strong ambition and interest of cities to drastically reduce energy use and GHG emissions in the mid and long term. However, the strong impulse given by cities to climate and energy policies raises the question of the impact local policies have in comparison to national policies. What is the impact of local policies compared to the national "baseline"? What is the additional effect of such strategies?

Cities are not autonomous entities but embedded in a multilevel governance framework of European and national policies as well as policies of federal states or other subnational levels. This fact is particularly relevant from a monitoring perspective since there is still no standard methodology to sufficiently differentiate the impacts of local and national climate policies in cities. Top-down CO_2-inventories, for example, cannot clearly differentiate between the impacts of local and national policies on emission levels. Both local and national authorities also fall into the trap of double counting.

The city of Hamburg decided to take on the challenge. Building on earlier energy and climate related activities, the city passed a very ambitious climate action plan with more than 400 CO_2 related policies and measures (incl. adaptation measures) in 2007, committed to a low carbon target until 2050 and defined an absolute annual reduction target of 2 million tons of CO_2 in the year 2012 compared to the year 2007 (top-down approach). In addition, the city tries to quantify the impact of both local and national policies on the city's emission level with the help of a bottom-up approach.

In the following section, we describe the interplay of municipalities and the federal government in the German climate policy regime. With the help of three examples, we discuss previously mentioned methodological challenges with respect to the interaction between national and local policies. We quantify the emission reduction effect of both national and local policies in Hamburg and we put special emphasis on methodological challenges that arise when separately measuring the impact of local and national policies on urban GHG emissions.

Cities and multilevel governance

MULTILEVEL GOVERNANCE

During the last two decades, climate politics to mitigate global warming has been characterized by a top-down paradigm (William et al., 2010). Especially the international negotiations during the Conferences of the Parties of the United Nations Framework Convention on Climate Change have received widespread attention. However, negotiations are tough, progress is little and there is an increasing number of voices that declare the strive for an international climate agreement to avoid dangerous anthropogenic interference with the climate system has failed (Geden, 2010; Rogelj et al., 2010; Anderson and Bows, 2011).

Against this background, the role of cities in tackling climate change has gained in significance. Yet local action is always embedded in a (inter-) national framework, which may support or hinder local commitment. Climate action therefore has to be horizontally and vertically integrated (Bulkeley and Betsill, 2005). To integrate climate action horizontally, cities have to work with other cities based on bilateral cooperation or through city networks. Both serve to enhance local expertise, facilitate best-practice transfer and help to find innovative solutions (Keiner and Kim, 2007). With respect to vertical integration, Corfee-Morlot et al. (2009) identify the following three possible institutional settings how local and national climate policies may be interlinked:

- Nationally led – "top-down" enabling framework.
- City led – "bottom-up" learning, from cities to national action.
- Hybrid Models.

In a "top-down" regime, national governments create a framework that enables local governments to implement climate policies, which means that local action is primarily driven by national policies. In contrast, in "bottom-up" regimes, local governments commit to tackling climate change even if there is no supporting national policy[2]. They commit to targets that go beyond national targets or to independently address climate change. Good practice and experiences at the local level may affect policies at the state or national level. In hybrid models national and local governments work in close cooperation to facilitate innovations and action at the local level (e.g. KLIMP[3] programme in Sweden).

There are several reasons why it is beneficial for (inter-)national governments to cooperate with local governments. First, many national policies have to be enforced on a local scale. Cities administer national programmes and due to their proximity to their residents may gain support for them more easily than national governments would do. Second, cities may serve as seedbeds for socio-technical innovations. Innovative policies can be tested in "real life" laboratories and may feed into national policy improvements (OECD, 2010; Schneidewind and Scheck, 2012).

CLIMATE POLICY REGIME IN GERMANY

The German climate policy regime is a typical example for a hybrid model. The EU roadmap "A Roadmap for moving to a competitive low carbon economy in 2050" constitutes the overall framework for a low-carbon transition of the EU countries. The roadmap intends to explore the most effective options for "decarbonising" the European economy and assesses ways to maximise benefits in terms of stimulating technological innovation, economic growth and job creation and strengthening energy security within the EU (EC, 2011). At the national level in Germany, the energy concept of the federal government from 2010 and the 'Integrated Energy and Climate Program' (Integriertes Energie- und Klimaprogramm) implemented in 2007 frame Germany's commitment and actions to reduce energy related emissions and foster climate protection (Hennicke et al., 2012).

The German government has committed to reducing GHG emissions by 40 percent by 2020 compared to 1990 (BMWi and BMU, 2010). So far, Germany has already achieved a 21 percent GHG emission reduction and thus met the target it committed to through the Kyoto Protocol (United Nations, 2012)[4]. The

2. The city of Barcelona passed its "Barcelona Solar Ordinance" in 2000 to regulate the use of solar thermal appliances for the production of hot water for buildings. The success of the ordinance motivated the Spanish government to develop a national policy, which requires the new and renovated buildings to cover 30–70 percent of their energy demand for hot water by solar systems (IEA, 2009).

3. Swedish funding schemes introduced by the national government to assist cities in climate change programme implementation.

4. Although analyses have shown that a significant proportion of that reduction is due to economic changes that occurred in East Germany after the fall of the Berlin Wall (Schleich et al., 2001).

current national energy concept outlines potential paths to reduce GHG emissions by 80 to 95 percent until 2050 (BMWi and BMU, 2010). Various policy packages have been passed to meet the target by stimulating thermal refurbishments of the existing building stock, inducing modernisation of the fossil-based energy supply sector, strengthening the role of renewable energy sources and reducing emissions in the transport sector. The most significant policies that are relevant at an urban scale are listed in Table 1[5].

Within this framework, local activities are directly supported by the federal government through a service agency for local climate mitigation actions[6] (dissemination of information, exchange on best-practices) and indirectly through the national climate protection initiative's incentive programmes[7]. So far, more than 1,000 local climate action plans have been funded through this national programme[8].

In addition to the top-down measures, there are several bottom-up approaches, although German cities are not yet obligated to take action on climate change. Currently, three main rationales motivate local authorities to develop additional climate protection measures and to tap further mitigation potentials: (1) an ethical commitment to global climate protection, (2) the wish to strengthen the regional economy, and (3) advance the regional image. However, in most German cities financial resources for voluntary climate protection have become quite scarce due to the past and present mounting of debts (Schüle and Scheck, 2012).

Methodological challenges to measure the impact of local and national policies on urban GHG emissions

To measure the impact of policies on urban GHG emissions two approaches are possible. Most cities have committed to ambitious GHG reduction targets and try to assess their achievements with the help of a top-down GHG inventory. The city of Hamburg aims to reduce its overall GHG gas emissions by 2 million tons by 2012 – compared to 2007 levels. Despite the existing challenges to compile an urban GHG inventory, it is the only way to assess whether the stated overall emission reduction goal has been achieved (Bader and Bleischwitz, 2009; Ibrahim et al., 2012). Yet, an inventory as a way of top-down monitoring is an inadequate instrument to monitor the effects of individual policies and measures. To assess the effectiveness of policies – which is here understood as the reduction of carbon dioxide emissions – bottom-up methodologies are required (Thomas and Schüle 2009). With respect to German national policies and measures entailed in the German energy concept, methodological approaches to evaluate their impact have been published recently (Doll et al., 2012). Yet, the proposed methodologies neglect the importance of cities in successfully implementing and enforcing national policies. Moreover, cities set up their own policies, such as the Climate Action Plan of the city of Hamburg. This leads to the following methodological challenges:

- **Impact assessment of national policies at local level.** To assess the impact of local and national policies with the help of a bottom-up methodology, valid data is required. Ideally, primary data on the energy use before and after any action induced by local and national policies should be available. However, depending on the kind of action, primary data is not available or the evaluation is too time-consuming and costly respectively. Therefore, assumptions have to be made, which lowers the level of accuracy. If reliable data is available, the questions is how do local and national policies interact and which policy is responsible for which share of the estimated emission reduction. Is a local policy complementary to a national policy or is its impact additional? If there are several measures and policies – on both political levels – with a similar objective in place (e.g. provision of information and consulting for thermal refurbishment of buildings), does every policy have an individual and additional effect or is there a saturation point. If there is one, how do we know it has been reached and how does it vary depending on the target group? Is it even possible and appropriate to isolate the impact of each policy?
- **Double-counting.** The risk of double-counting the effects of national and local policies mainly results from the fact that often two or more policies aim to achieve the same goal. For instance, in Germany financial support of a thermal refurbishment by the state-owned bank KfW (national policy) can be supplemented with additional funding provided by the local government. Yet, neither the national nor the local policy demand the collection of data on whether an individual thermal refurbishment is also being financially supported by other public actors. Considering just the individual data of the national and local government on how many thermal refurbishments have been supported it is therefore possible to count twice the same projects and thereby to overestimate the emission reduction. This raises the question on how double-counting can be avoided in order to get a sound calculation of the impact local and national policies have on urban emissions.
- **Impact assessment of external factors.** Climate-related actions do not only take place due to existing policies. Even if people are not intrinsically motivated, external factors (e.g. energy prices, lifestyle changes etc.) affect the impact of policies. For instance, what is the main reason to purchase an energy efficient vehicle? Is the decision based on individual preferences of the purchaser, is the decision driven by increasing fuel costs, are incentives (e.g. grants, subsidies) by the local or national government decisive or does the combination of all factors contribute to the event?

In addition to the top-down CO_2-inventory, the local government of Hamburg commissioned the development of a detailed bottom-up methodology[9] to monitor the effect of its Climate

5. EU Directive: This does not necessarily mean that the national policy has been implemented after the EU Directive has been passed (e.g. the EEG was introduced in 2001, while the EU Directive was passed in 2009). However, all national policies can be considered means to attain the goals defined in the respective Directive.

6. http://www.klimaschutz-in-kommunen.de/ (German).

7. Since 2009, the German Ministry for the Environment has been funding the development of local climate action plans that have enabled cities and local authorities to develop coherent and integrated climate protection strategies.

8. http://www.kommunaler-klimaschutz.de/förderprogramme/bmu-förderprogramm/zahlen-und-fakten.

9. We measure CO_2 emissions without upstream emissions or CO_2 eq. An exception is the emission factor of electricity, which is based on the existing mix of nationally existing power plants. District heating is measured through the locally existing capacities.

Table 1. National climate policy instruments in Germany.

Sector	National policy instruments	Brief description	EU Directive
Energy Efficiency	Energy Saving Ordinance (EnEV)	Ordinance to define minimum energy-efficiency standards for new buildings and buildings that undergo extensive renovations. Requirements are tightened step by step.	Directive 2010/31/EU – on the energy performance of buildings
	Energy Saving advice (Energieberatung vor Ort, BAFA)	Instrument to fund energy saving advice for owners of residential buildings. The goal is to develop a concept for thermal refurbishments and use of renewable energy sources in order to lower energy demand and emissions of the building	Directive 2010/31/EU – on the energy performance of buildings
	Energy Saving advice for companies (Energieberatung Mittelstand)	Instrument to fund energy saving advice for SME (small and medium enterprises).	Directive 2006/32/EC – on energy end-use efficiency and energy services
	Smart-Metering	Due to an amendment in the German Energy Act (EnWG), smart meters have to be installed in new buildings and in those which undergo extensive renovations from 2010 on. Thereby, households will receive information about their electricity consumption. It is hoped that this will lead to an increased awareness and thus to a decreasing energy demand	Directive 2006/32/EC – on energy end-use efficiency and energy services
	KfW "Energy-efficient Construction" and " Energy-efficient Renovation"	Soft loans and grants to facilitate thermal refurbishment of existing buildings and for new buildings achieving more ambitious energy performance standards than required by the EnEV	Directive 2010/31/EU – on the energy performance of buildings
	Thermal refurbishment of social infrastructure	Grants to enhance energy performance of social infrastructure buildings (schools, kindergardens etc.)	For public buildings: Directive 2006/32/EC – on energy end-use efficiency and energy services
Energy Generation	Renewable Energy Sources Act (EEG)	Act on granting priority to renewable energy sources with the aim of increasing the share of renewable energy sources in electricity supply. It guarantees the producer a fixed feed-in remuneration for a certain time period	Directive 2009/28/EC – on the promotion of the use of energy from renewable sources
	Combined Heat and Power Act (KWKG)	Act on the maintenance, modernisation and expansion of combined heat- and-power generation plants. Similar to the EEG, network operators are obligated to connect CHP plants to the grid and to purchase the produced electricity, which is remunerated by a bonus additional to wholesale market prices	Directive 2004/8/EC – on the promotion of cogeneration based on a useful heat demand in the internal energy market
	Market incentive program (MAP)	Programme to encourage the use of renewable energy technologies to generate hot water and cover space heating needs through the granting of subsidies and low interest-loans. Solar thermal installations, heat pumps and biomass heating are eligible for financial support. Target groups are private households, companies and municipalities	Directive 2009/28/EC – on the promotion of the use of energy from renewable sources
Transportation	Biofuel Quota Law	Law which has been applicable since January 2007 and obligates mineral oil companies to use an increasing rate of biofuels in their fuel blends.	EU Directive 2003/30/EC – on the promotion of use of biofuels or other renewable fuels for transport
	CO_2 Strategy private vehicles	Regulation to define a maximum level of emissions for new cars. Standards are gradually tightened with the aim of reducing the emissions level of new passenger cars to 95 g/km by 2020	Regulation (EC) No 443/2009 – setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO2 emissions from light-duty vehicles
	CO_2-based motor vehicle tax	Regulation to calculate the motor vehicle tax of new cars based on cylinder capacity as well as their CO_2 emissions. Additional fees have to be paid if CO_2 emissions exceed 110 g/km (2012)	
	Passenger car consumption labelling	Regulation to oblige car dealers to inform customers about energy consumption and emissions of their cars.	
Cross Sectoral	European Union Emission Trading Scheme (EU-ETS)	Power and heat generating plants as well as energy-intensive industry sectors are covered by the EU-ETS. Companies in these sectors are required to hold emission allowances equivalent in number to their emissions. Due to a reduction of the total number of allowances, it is ensured that the emissions of all plants subject to the emission trading system are as well reduced.	Directive 2009/29/EC as to improving the greenhouse gas emission allowance trading scheme (emissions trading directive)

Source: own compilation.

Action Plan (Schüle et al., 2009). Within the implemented monitoring scheme, local authorities have to collect data on the reduction of energy use and CO_2 emissions associated with an individual measure in exchange for being granted funding within the Climate Action Plan. The data to be collected differs for individual measures and is described in Schüle et al. (2009).

Hamburg – climate change action between national and local commitment

The discussion above shows the significance of both, local and (inter-)national policies to mitigate climate change. The general situation in Germany, e.g. local and national capacities to act and the roles local governments and the federal government may play, has been examined by various studies and is briefly described above (Kern et al., 2005; Bulkeley and Kern, 2006). We now take a closer look at the specific conditions in the city of Hamburg and here particularly at the interactions between national and local climate change policies.

CLIMATE CHANGE ACTION IN HAMBURG

The action plan for the city of Hamburg contains various measures and policies in the following fields of action: building sector, mobility sector, industry and plant technology, national and international cooperation, climate impact management and adaptation, research and evaluation and monitoring. Currently, more than 300 measures and policies – initiated by local and national actions – are being implemented or are planned to be implemented within the city's boundaries. Figure 1 shows the number of measures per sector. In total, more than 23 million EUR were allocated by the city of Hamburg to finance measures of the climate action plan in 2011. More than 79 percent of this amount was used in the sectors energy, buildings, mobility and industry and plant technology.

At the same time, the local government is aware that the local CO_2-emissions are influenced by national and intergovernmental policies, technological changes and industrial activities, which can hardly be addressed through local policies. Therefore it was estimated in 2007 to what extent the activities in various sectors could contribute to the goal of reducing CO_2 emissions by 2 million metric tons within five years. Based on potential analyses and expert assessment, the impact of national policies was expected to amount to 450,000 t CO_2. An additional reduction of 550,000 t CO_2 was supposed to be achieved through quantifiable local measures and policies. Actions of Hamburg's industrial companies, to which they committed themselves, were supposed to further decrease local CO_2 emissions by 500,000 metric tons. Not quantifiable measures and policies as well as technological progress were estimated to induce emission reductions of 500,000 t CO_2. Now, more than five years after the climate action plan was passed by the local parliament, we have evaluated the impact of local and national policies.

Since the local government's goal is formulated with respect to the city's overall emissions, the city needs to monitor its emission level. This is achieved by annually compiling a local GHG inventory. Currently, results are available for the years 1990 to 2010. During the compilation of inventories, one has to consider different measurement boundaries, which can be distinguished according to the scope concept (Ibrahim et al., 2012). While scope 1 only attributes emissions caused by the consumption of primary energy sources within the city's boundaries to the city, scope 2 also adds emissions which are caused by the city's consumption of electricity and heat produced outside the city limits. Scope 3 further considers emissions caused by the consumption of other goods and services, which are produced outside the city limits. Since Hamburg's goal is formulated in regard to an inventory compiled according to scope 2, we will hereafter refer to a scope 2-inventory when speaking of local GHG emissions[10].

Hamburg's GHG emissions in the year 2010 were calculated to amount to 18.3 million metric tons. Compared to the city's GHG emissions in 2007, which were at 17.6 million t, one has to note an actual increase of emissions by 0.7 million tons. Yet, with respect to 1990 GHG emissions of 20.7 million tons one can still find a reduction of overall emissions by 12 percent. Nevertheless, the question on what this means for calculating the effects of local and national policies remains unanswered. Emission reductions due to individual measures are mostly calculated by comparing the state after the implementation of a measure with a reference state. This is explained in detail when the methodology used to calculate the emission reductions of the exemplary policies is presented.

In 2010, GHG emissions of 8.7 million t were caused by the energy use of private households and small and medium enterprises, while the industrial and mobility sector's energy demand was responsible for emitting 5.4 and 4.2 million tons of GHG respectively. With 9.2 million tons roughly half of the city's emissions were due to the consumption of electricity and heat (Länderarbeitskreis Energiebilanzen, 2012).

INTERDEPENDENCY OF LOCAL AND NATIONAL POLICIES IN HAMBURG

To understand the interdependency of local and national policies in Hamburg, we exemplarily describe our methodological approach for the following three examples:

- Development of renewable energy sources for generating electricity.
- Combined heat and power generation.
- Energy efficiency improvements for new residential buildings.

We chose those examples among the different local and national policies we examined because a) they are relevant with respect to their absolute emission reduction in Hamburg b) they cover different types of policies (e.g. regulation, incentives etc.) c) they include different energy saving and energy generation technologies and d) they are representatives for specific methodological challenges that also occur considering the other examined instruments and policies at both local and national level.

Development of renewable energy sources for generating electricity

Description of the framework

In Germany the use of renewable energy (e.g. wind, solar and biomass) in electricity generation is mainly supported by the provisions of the Renewable Energy Sources Act (Erneuerbare-

10. This scope is standard for most cities in Germany and abroad. However with a world becoming more and more globalised, production-based GHG inventories may be misleading. Scientific discussions are emerging to rather introduce consumption-based inventories as to avoid a shift of emissions from cities in developed countries to developing countries (Schulz, 2010; UN-Habitat, 2011).

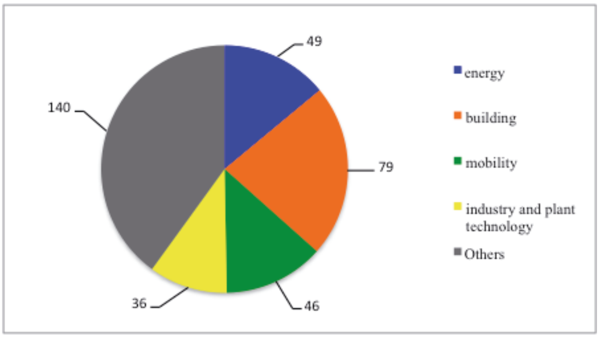

Figure 1. Number of local and national climate actions in Hamburg by field of activity. Source: (Hamburg Parliament, 2011).

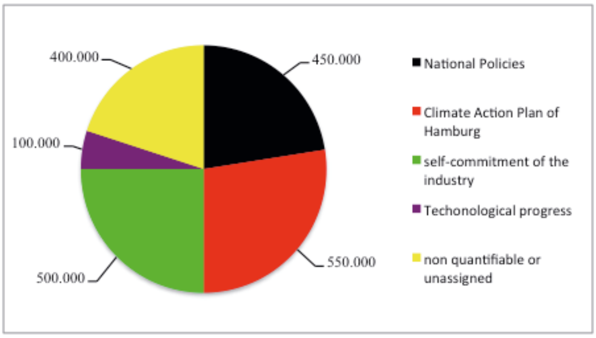

Figure 2. Ex-ante estimated contributions of activities to the overall emission reduction goal. Source: Schüle et al. (2011).

Energien-Gesetz). The act introduces several conditions, such as guaranteed grid access, the obligation for grid operators to feed in electricity generated from renewable energy sources with priority and a remuneration per kWh for 20 years to facilitate investments in renewable energy technologies.

Within the framework of the Climate Action Plan, the city of Hamburg is also pursuing activities to increase the use of renewable energy sources in electricity and heat generation. These actions include measures to facilitate the deployment of innovative technologies (e.g. thin-film photovoltaics), studies on the local potentials of renewable energy sources and the erection of renewable power plants and wind farms on areas owned by the city[11].

Methodological approach

In our approach, the emission abatement due to the Renewable Energy Sources Act is estimated by constructing a reference case, in which the same amount of electricity is assumed to be produced by thermal power stations employing non-renewable energy sources. Emission factors which differ depending on the technology employed (e.g. wind, photovoltaics, hydroelectric) are calculated. The factors are derived based on assumptions on which mix of non-renewable technologies would have generated the electricity produced with the respective renewable energy source if it had to be substituted. The factors utilized in this study are based on assumptions by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety based on studies by Klobasa and Sensfuß (2011), who use an electricity market model to determine these factors (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2012). To estimate the emission abatement for the city of Hamburg, data from the local distribution system operator (DSO) is used. This includes the amount of generated electricity, the installed capacity and the commission date for every renewable power plant. For this paper, two estimations of the abated emissions were calculated for every year from 2007 to 2011. The estimation of the abated emissions was calculated only for power plants commissioned on January 1st or later and for every year from 2007 to 2011. This was done because the city of Hamburg is solely interested in the emission reductions achieved by political action since 2007, due to its commitment period defined in the climate action plan.

While certain assumptions made in calculating the emission reduction might be discussed, the general approach is straightforward and plausible. In contrast the question which policy is responsible for which percentage of the emission reductions is much more difficult.

The Renewable Energy Sources Act creates the necessary condition to make renewable power generation financially interesting to potential investors. Still, the question whether the provisions of the Renewable Energy Sources Act alone are sufficient to enable the construction of an individual renewable power plant is still open. With respect to a wind farm constructed in the Hamburg port area, for example, the city owns the areas on which the turbines were erected and the plants would not have been built without the continuous (and conflictual) engagement of the municipality, despite the incentives set by national regulation. Independently of individual plants situated on city-owned land, one could also reason that municipalities constitute a veto player, i.e. an "individual or collective actor whose agreement is required for a change of the status quo" (Tsebelis, 1995), because municipalities have to grant permission for the construction of plants within their city limits.

Yet, all these arguments do not allow one to unambiguously identify the condition sine qua non for the construction of renewable power plants and the hereby-induced emission reductions. Therefore we resorted to defining our own conventions when it comes to attributing the effects to local or national policies:

The emission reductions are completely attributed to national policy when plants are situated within the city limits, but on privately owned ground. One exemption, where emission reductions are also partly attributed to a local policy, is a programme to financially assist the installation of thin film photovoltaics introduced by the local government.

In cases when plants are situated on land (directly or indirectly) owned by the city or when the installation of innovative technologies (thin film photovoltaics) is supported, we take into account that the city has accelerated procedures and that the individual plant has been commissioned earlier. Therefore we attribute the emission reduction in the first two years after commissioning to the city of Hamburg. This is equivalent to 10 % of the total emissions reduction of the plant during its (assumed) operative life-span[12].

11. In the latter case it has to be borne in mind that these expenditures are expenditures within an investment project with a normally positive net present value.

12. This is a convention based on conclusions drawn from the aforementioned arguments. Studying these questions with data on treatment (i.e. cities with policies additional to the national framework) and control groups (i.e. cities without policies additional to the national framework) while controlling for other factors (e.g. local potentials) seems warranted, but could not be conducted within this study.

Table 2. CO_2 emission reduction due to the development of renewable energy sources for generating electricity.

		2007	2008	2009	2010	2011
CO_2 emission reduction by instrument						
EEG – total impact	t CO_2	6.752	14.648	29.004	29.954	39.762
CO_2 emission reduction by policy level						
Local policies	t CO_2	0	8	183	679	2.899
National policies	t CO_2	6.752	14.640	28.821	29.275	36.863

Results

The support of renewable energy sources for power generation has saved 39.762 metric tons of CO_2 in 2011, when considering only those plants commissioned on January 1st 2007 or later[13]. Table 2 displays the respective results for the years 2007 until 2011.

Combined heat and power generation

Description of the framework

As with renewable energy sources, co-generation as a means to generate electricity and heat more energy-efficiently is supported by the federal government. The most important instrument employed by national policy makers to expand the practice of cogeneration is the Combined Heat and Power Act (Kraft-Wärme-Kopplungsgesetz) (see Table 1). Grid access for cogeneration plants is guaranteed by law and grid operators having to feed in electricity generated in cogeneration with priority.

The Climate Action Plan of the city of Hamburg also contains several measures to expand the use of co-generation. In particular there is a measure which both funds studies to assess the potential for combined heat and power (CHP) in small and medium enterprises and large housing estates and provides financial support for investments in CHP (Hamburg Parliament, 2011).

Methodological approach

The methodology employed to calculate the emission reduction due to co-generation works by constructing a reference case. Like for renewable energy technologies, this means that this method does not estimate an emission reduction compared to the emission level of a base year, but compared to the current year's emissions without the use of co-generation.

Due to limited data availability, two methods were applied. For co-generation plants with an electrical generation capacity of 1 MW or higher, data collected by the state's statistical agency could were used. The data contains the primary energy input, electricity and heat generated, each differentiated for several primary energy sources. With this data the emission reduction is calculated by following formula, considering the difference between the emissions from the CHP plant and monovalent electricity and heating plants (reference plants) generating the same amount of electricity and heating energy (Gores et al., 2011):

$$\Delta EM_{CO_2} = \sum_{i=1}^{n} (W_i^{CHP} * e_i^{CHP}) - (A_i^{CHP} * e_{ref}^{A} + Q_i^{CHP} * e_{KWK}^{Q}),$$

Where

ΔEM_{CO_2} denotes the emission reduction.

W_i^{CHP} denotes the primary energy input of primary energy source *i* in the CHP plant.

e_i^{CHP} denotes the emission factor of primary energy source *i*.

A_i^{CHP} denotes the electricity generated by primary energy source *i*.

e_{ref}^{A} denotes the emission factor of a reference system of power generation (monovalent system).

Q_i^{CHP} denotes the heat generated by primary energy source *i*.

e_{KWK}^{Q} denotes the emission factor of a reference system of heat generation (monovalent system).

For e_{ref}^{A} we used the value 770 g CO_2/kWh. The emission factor of the reference system of heat generation is set to 295 g CO_2/kWh (Gores et al., 2011).

Since the goal of the city of Hamburg is to estimate the emission reduction with respect to 2007 emissions, we had to decide how to determine this value with no information on the commission date of individual cogeneration plants. We chose to treat the 2007 emission reduction as a baseline and regard any additional emission reduction in the subsequent years to be the sought value. We are aware that this is only a rough approximation since the electricity and heat produced in any given year is only partially determined by the total capacity of cogeneration plants. Other factors on which these values are dependent include heat demand and economic considerations.

With regards to the question to whom the emission reduction of co-generation policy should be attributed, our approach is twofold. The local policy is mainly aimed at supporting the installation of small CHP plants. The electricity and heat generated by these plants is not included in the statistical data as

13. Considering every plant in Hamburg, which was built under the EEG the total CO2 emission reduction would be 171.374 metric tons in the year 2011.

Table 3. CO_2 emission reduction due to combined heat and power generation.

		2007	2008	2009	2010	2011
CO_2 emission reduction by instrument						
Cogeneration	t CO_2	0	12.102	200.311	433.226	200.857
CO_2 emission reduction by policy level						
local policy	t CO_2	0	0	12.688	22.066	22.431
national policy	t CO_2	0	12.102	187.623	411.159	178.426

long as their electric capacity is lower than 1 MW. Since data on capacity and the primary energy source employed is available for every CHP plant built with financial support by the city, we estimate the emission reduction due to the operation of these plants individually. In cases where electric capacity is higher than 1 MW, we subtract the estimated primary energy source input, electricity and heat generation from the statistical values for the corresponding energy sources.

This leaves the following assumptions:

- If the construction of a CHP plant is not financially supported by the city, the emission reduction due to the practice of co-generation is completely attributed to federal policy[14].
- If the construction of an individual CHP plant is financially supported by the city, the emission reduction due to the more efficient production of heat is attributed to local policy while the emission reduction due to the more efficient production of electricity is attributed to federal policy. The production of electricity in cogeneration is remunerated with a bonus as provided for by federal law. Yet, when the construction of CHP plants is also financially supported by the local government, it is assumed that the additional incentive was needed and provided for by the local government[15].

Results

The values of Table 3 are calculated based on the previous assumptions.

Energy efficiency improvements for new residential buildings

Description framework

Two main national policies affect the energy efficiency of new residential buildings[16]. The Energy Saving Ordinance (EnEV) defines minimum energy requirements and the KfW funding programme "Energy-efficient Construction" provides soft loans and grants to achieve more ambitious energy performance standards (KfW 70/55/40 standards, passive house standard) than required by the EnEV. On the other hand several support programmes provided by the city of Hamburg like the housing loan association (Hamburger Wohnungsbaukreditanstalt (WK)) etc. facilitate the construction of energy efficient new buildings. The WK has a support programme in place in order to subsidies new residential buildings that achieve higher energy performance standards than required by the EnEV. This funding is available in addition to the KfW support programme. Further local policies to raise awareness among residents and to enforce current regulations[17].

Methodological approach

Approx. 18,000 new living units have been built in Hamburg between 2007 and 2011. 13,400 were funded by the KfW and 12,400 by the WK. The figures indicate that most of the living units were double funded. It was not possible to determine how both programmes influence investor decisions. Therefore we account an equal share of the measured CO_2-reduction to both programmes[18]. In the period considered, the EnEV has been tightened twice. We compared the currently applicable EnEV standard (useful energy) for detached houses and multi-family homes with the former applicable EnEV standard. EnEV standards were taken from the HEAT-Model carried out by the Wuppertal Institute (Ifeu/Wuppertal Institut 2009). The measured CO_2 reduction is completely attributed to the national policy instrument. Moreover, a lack of enforcement of the EnEV has been proved by several studies, which found up to 25 percent non-compliance (Diefenbach et al., 2006). We used a more conservative approach and assumed a 10 percent non-compliance, which may be lowered due to local actions (e.g. awareness campaigns, energy consulting). The CO_2-reduction of the KfW funding programme is regularly evaluated by a consortium of

14. Local governments have the authority to make it mandatory to connect buildings to district heating in certain areas. We abstracted from this case.

15. It might also be that the additional support is merely maximizing the profits of plant owners and the CHP plant would have also been constructed in absence of the local policy. This could neither be verified nor falsified based on the available data.

16. The Renewable Energy Heat Act (EEWärmeG) is also important considering a holistic perspective on the energy performance of buildings. Yet, so far no data is available to measure the impact of the policy.

17. For more detailed information about existing local policies in Hamburg, see Hamburg Parliament (2011).

18. The number of living units funded by WK and KfW is almost equal. Yet, no data is available to show whether the same living units were funded. We therefore assume that investors use both funding programmes to lower their investment costs and by this neglect the possible option that an investor either uses KfW or WK funding.

different research institutes. We used the published figures[19]. The WK evaluates its funding programme itself and assumes an average energy performance standard of 55 kWh/m^2 (final energy) for all funded living units. We compared this figure with the current applicable EnEV standard. As the lifespan of building projects is longer than the time period considered here the measured CO_2 reductions per year were cumulated. Figure 3 illustrates the methodological approach used.

Results

Due to energy efficiency improvements in new buildings, CO_2 emissions in Hamburg have been reduced by approximately 9,000 metric tons in the period from 2007 to 2011. Data show that the tightening of the EnEV has the largest impact on the emissions. Yet, local policies have the potential to further decrease emissions. At least a quarter of the total CO_2 emission reduction is driven by local actions.

RESULTS: BOTTOM-UP EVALUATION OF NATIONAL AND LOCAL POLICIES AND THEIR IMPACT ON HAMBURG'S EMISSIONS LEVEL

We have estimated emission reductions for more than the three policies previously described. In total, all considered policies have resulted in a CO_2 emissions reduction of 3.1 million metric tons between 2007 and 2011 in Hamburg. CO_2 emission reduction was more than 800,000 metric tons in 2011. The data shows that the various national policies have different impact on Hamburg's emission level. By comparing the achieved reduction to the ex-ante postulated emission reduction potential of national policies from 2007, it becomes obvious that their impact has been underestimated. There are two main reasons for this. First, several national policies have been tightened in the considered time period, new policies were introduced and policies could benefit from external factors[20], which could not have been anticipated in 2007. Second, the underestimation underlines the common assumption of local governments that they have noticeable control of their own emission level and related capacities to influence the implementation of national policies.

The Climate Action Plan of the city of Hamburg contains both measure which are related to national policies as well as measures which do not have any relation to national policies. The emission reduction for the latter measures is as well calculated bottom-up, i.e. the reduction of energy consumption and emission is estimated individually for every measure. Since the exact methodology is dependent on the type of the measure, we will not further elaborate on the methods used to calculate the emission reduction of these local policies[21]. The following table shows the estimated values for the overall emission reduction of all measures within the Climate Action Plan of Hamburg, for which an estimation of the emission reduction could be conducted.

19. The evaluation of the KfW funding programmes does not attribute CO2 emission from district heating and from power generation to the consuming households. Instead it is attributed to the transformation sector. Therefore, the evaluation underestimates the CO2 reduction in Hamburg with approx. 10–15 % of all new residential buildings being heated by district heating.

20. E.g. energy price increase, increasing cost-competitiveness of renewable energies, behavioural changes due to changes in values and preferences.

21. For more details see Schüle et al. (2009).

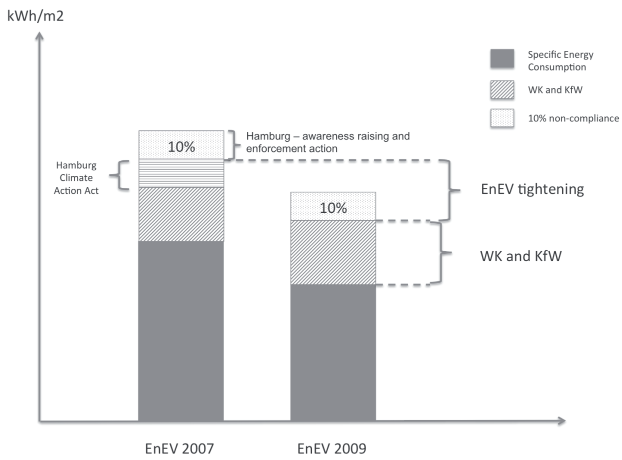

Figure 3. Methodological approach to measure the impact of local and national policies with respect to energy efficiency improvements for new residential buildings in Hamburg.

Conclusion and key findings

Considering the assumptions used to attribute the savings to either local or national policies, the analyses show that the quantitative impact of national policies is significantly higher than assumed ex-ante. Nevertheless, cities remain crucial actors in the German climate policy regime mainly because of their possibilities for defining additional measures and complementary supporting structures. In Germany, an increasing activism among administrations, policy makers and voters and an increasing share of government budgets – whether federal or municipal – allocated to climate-related policies has been observed in the last years. Yet, this raises the need for a fair evaluation of their impact. The case of Hamburg points out that there are several policy and methodological challenges – and pitfalls – to properly address the impact of national and local policies.

From a policy perspective these are:

- **Local action is embedded in a national policy framework** – Cities are expected to play a key role in mitigating climate change. However, their actions both benefit from, and are restricted by, a national policy framework. Many policies, like energy efficiency standards for appliances and buildings or efficiency standards for vehicles are already implemented – and more easily and more effectively so – by national governments. Local action to mitigate climate change therefore requires a thorough and honest analysis of local capacities and competencies and how to most effectively utilize them to reach the stated objectives.
- **The different local and national capacities to mitigate climate change** – The ex-ante estimation and the ex-post impact evaluation of local and national policies on Hamburg's GHG emissions level points to a gap in the estimate of local capacities to mitigate climate change. Many cities consider their potential emission path to be a result of their own commitment and engagement to tackle climate change. Yet, the bottom-up analyses and the top-down GHG inventory reveal a slightly different picture – the impact of national policies is noticeably higher than expected ex-ante. However, it must be recognised that the analyses only focused

Table 4. CO_2 emission reduction due to energy efficiency improvements in new residential buildings.

		2007	2008	2009	2010	2011
CO_2 emission reduction by instrument						
EnEV - 10% non compliance	t CO_2	1.319	2.799	3.651	4.343	5.143
EnEV	t CO_2	1.199	2.544	3.319	3.948	4.676
10% non-compliance	t CO_2	120	254	332	395	468
WK and KfW Funding	t CO_2	633	1.547	2.306	2.762	3.257
Sum	**t CO_2**	**2.072**	**4.600**	**6.289**	**7.499**	**8.868**
CO_2 emission reduction by policy level						
local policies	t CO_2	436	1.028	1.485	1.776	2.096
national policies	t CO_2	1.635	3.572	4.804	5.724	6.772
Sum	**t CO_2**	**2.072**	**4.600**	**6.289**	**7.499**	**8.868**

Table 5. CO_2 emission reduction due to national policies in Hamburg.

		2007	2008	2009	2010	2011
EU-ETS	t CO_2	0	179.448	207.188	44.233	201.404
Renewable Energy Sources Act (EEG)	t CO_2	6.752	14.648	29.004	29.954	39.762
Combined Heat and Power Act (KWKG)	t CO_2	0	12.102	200.311	433.226	200.857
Market incentive program (MAP)	t CO_2	891	3.034	4.968	5.518	6.178
Energy Saving advice (Energieberatung vor Ort, BAFA)	t CO_2	93	239	396	476	558
Energy Saving advice for companies (Energieberatung Mittelstand)	t CO_2	0	3.496	7.539	10.089	23.766
Smart Metering	t CO_2	0	0	0	808	2.626
Energy Saving Ordinance (EnEV) (new residential buildings)	t CO_2	1.319	2.799	3.651	4.343	5.143
Biofuel Quota Law	t CO_2	292.907	216.061	199.407	206.191	199.212
CO_2 Strategy private vehicles, CO_2-based motor vehicle tax, passenger car consumption labelling	t CO_2	0	0	17.777	39.407	91.556
KfW "Energy-efficient Construction" and "Energy-efficient Renovation"	t CO_2	5.462	14.987	35.782	57.156	67.870
Energetic retrofit of social infrastructure	t CO_2	0	0	0	0	91
Sum	**t CO_2**	**307.424**	**446.814**	**706.023**	**831.401**	**839.023**

Table 6. CO_2 emission reduction due to local policies in Hamburg.

		2007	2008	2009	2010	2011
total	t CO_2	25.542	85.383	178.832	271.024	397.339
attributed to local policy	t CO_2	22.603	71.247	142.914	210.109	311.085

on a limited number of quantitatively measurable local policies. In order to achieve countable effects, comprehensive packages of policies in relevant sectors are required, backing up financial and legal incentives at different levels e.g. by education programmes, information and advice. For this reason, concluding that there is no need for local policies to tackle climate change would be wrong, though further research on how an optimal policy package in the national multi-level governance system would have to be designed to maximize the impact of local policies is warranted. Cities are important actors in the transformation process of energy infrastructures and energy consumption patterns towards a low carbon society. They are important "transmission belts" in implementing national policies at local level in their role as role models, as planning institutions and regulators, as suppliers, operators and investors and finally as promoters.

- **Policy integration at a local and national level is limited** – There is only limited integration and co-ordination of activities at different political levels, which may result in ineffective policies.
- **Political will to measure the impact of local and national policies separately –** Our experiences with the city of Hamburg show that there is an urgent political will to isolate the impact of local policies from those of national policies. Investments in climate-related actions by a municipality cause opportunity costs (e.g. less investment in social infrastructure). Therefore local governments require quantified figures to legislate their decisions. From a scientific perspective so far it is neither always possible nor appropriate to isolate the impact of each individual local and national policy as there is a lack of data availability and there is usually no clear and simple linearity where one policy has only one single effect. Nevertheless, the existing political will is to be seen as a task for the scientific community to develop methodologies and guidelines for an appropriate way to measure the impact of individual policies or policy packages. Our approach is to be seen as a first rough attempt to nudge the discussion.

With respect to above described methodological challenges further research and improvements are needed in the following fields:

- **Strengthening the role of bottom-up evaluations is needed** – Hitherto, the role of top-down GHG-inventories at local level has been overestimated. Inventories are not able to measure the effects of single measures and not even of sectoral policies. Top down inventories are helpful tools so monitor the emissions of one city and serve as a communication tool in political debates. As a tool for monitoring policies and measures, their contribution is rather limited.

  To monitor the effects of climate policies, cities should complement top-down inventories with sound bottom-up approaches. Such bottom-up schemes should both assess the effects of national policies in one city and the effects of the additional measures implemented at local level. The monitoring scheme should also entail activities of none-public actors such as the local industry, local housing companies, etc.
- **Enhance the existing monitoring regime** – At national level, there is a need to support cities in developing their monitoring regime e.g. by providing information, bottom-up calculation tools etc. Our results reveal that more data has to be collected, when above mentioned challenges are to be answered, e.g. on simultaneous use of national and local support programmes. Our results are based on several assumptions and thus remain subject to a degree of uncertainty. But, given an interest in evaluating the effects of local and national policies and finding options for enhancing their impact, the research question is still relevant.
- **The unknown impact of external factors –** The common practice to measure the impact of policies is based on collecting measurable and quantifiable data (e.g. number of energy consulting activities, installed capacity of renewable energy sources etc.) and allocating them to the considered policy. This is also our approach. However the question of responsibility remains unsolved meaning that it is probably not only the policy itself that causes action but external factors. Here further research is needed to evaluate the effect of external factors.

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